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REGIONAL TILL GEOCHEMISTRY AND SURFICIAL GEOLOGY OF THE WESTERN AVALON PENINSULA AND ISTHMUS

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ABSTRACT

Mapping of the surficial geology, and a regional survey of till geochemistry were completed on the western part of the Avalon Peninsula; this included the Isthmus and the southern half of the Bay de Verde Peninsula. Previous reconnaissance surficial mapping was ground-verified, and the ice-flow indicators were mapped to reconstruct the paleo ice-flow history. Till was sampled at a density ranging from 1 sample per 1 km^2 in areas of good access to 1 sample per 4 km^2 where helicopter support was required. A total of 1042 samples were collected.

The entire area, which is subdivided into 4 discrete subareas, was ice-covered during the late Wisconsinan. North of the Doe Hills, ice flow was generally eastward from the main Newfoundland ice cap, likely centred on Middle Ridge in central Newfoundland. Sediment dispersal distances in this area are potentially large (greater than 5 km), as indicated by provenance of clasts within the till. The southern part of the Isthmus was covered by ice from a local source centred on the Collier Bay Brook–Tickle Harbour Station area; ice flow was radial, and dispersal distances are short (much less than 5 km). The southern part of the Bay de Verde Peninsula was covered by northward-flowing ice from the main Avalon dispersal centre at the head of St. Mary's Bay. This ice flow produced an extensive Rogen moraine field that extends as far north as Makinsons. The central part of the Bay de Verde Peninsula maintained an independent ice centre during the late Wisconsinan, likely deflecting St. Mary's Bay ice into Trinity and Conception bays. Dispersal distances over much of the Bay de Verde Peninsula are likely short (less than 5 km).

Areas of glaciofluvial sediment indicate the paths of meltwater during glacial retreat. The effect of regional isostatic rebound was to produce raised marine features around much of the coastline, up to about 16 m above the modern sea level. Drift-exploration programs in these areas should be conducted with caution.

INTRODUCTION

This project continues regional surficial and till geochemistry mapping in eastern Newfoundland, that began in 2000 on the Bonavista Peninsula (Batterson and Taylor, 2001a, b). The efficacy of this project was demonstrated recently by interest from mineral-exploration companies and prospectors following the Bonavista open-file release (Batterson and Taylor, *op. cit.*), which generated the staking of 1045 new claims having a value of $62 300, within the first 5 days of its release. This response was mirrored by results from other, similar projects, including those covering Grand Falls–Gander (Batterson *et al*., 1998), Hodges Hill (Liverman *et al*., 2000), Roberts Arm (Liverman *et al*., 1996), and southern Labrador (McCuaig, 2002).

These projects combine surficial mapping (a combination of aerial photograph analysis and field verification), paleo ice-flow mapping and sampling of till for geochemistry analyses. The latter two elements are complete for this project, although further surficial geology mapping is required.

LOCATION AND ACCESS

The Avalon Peninsula is located in the eastern part of the province, comprising an area of about 9700 km^2, and that has a population of about 300 000 (over 60 percent of the total population of the province). The Avalon Peninsula is connected to the rest of the island by the Isthmus, which is only 6.3 km wide at its narrowest point.

This project covered eight 1:50 000-NTS map sheets extending from the Clarenville area across the Isthmus, and continuing north of the Trans-Canada Highway up the Bay de Verde Peninsula to the Victoria–Heart's Content road (Route 74). Map sheets included were: 1N/5, Argentia; 1N/6, Holyrood; 1N/11, Harbour Grace; 1N/12, Dildo; 1N/13, Sunnyside; 1N/14, Heart's Content; 1M/16, Sound Island; and 2C/4, Random Island (Figure 1).

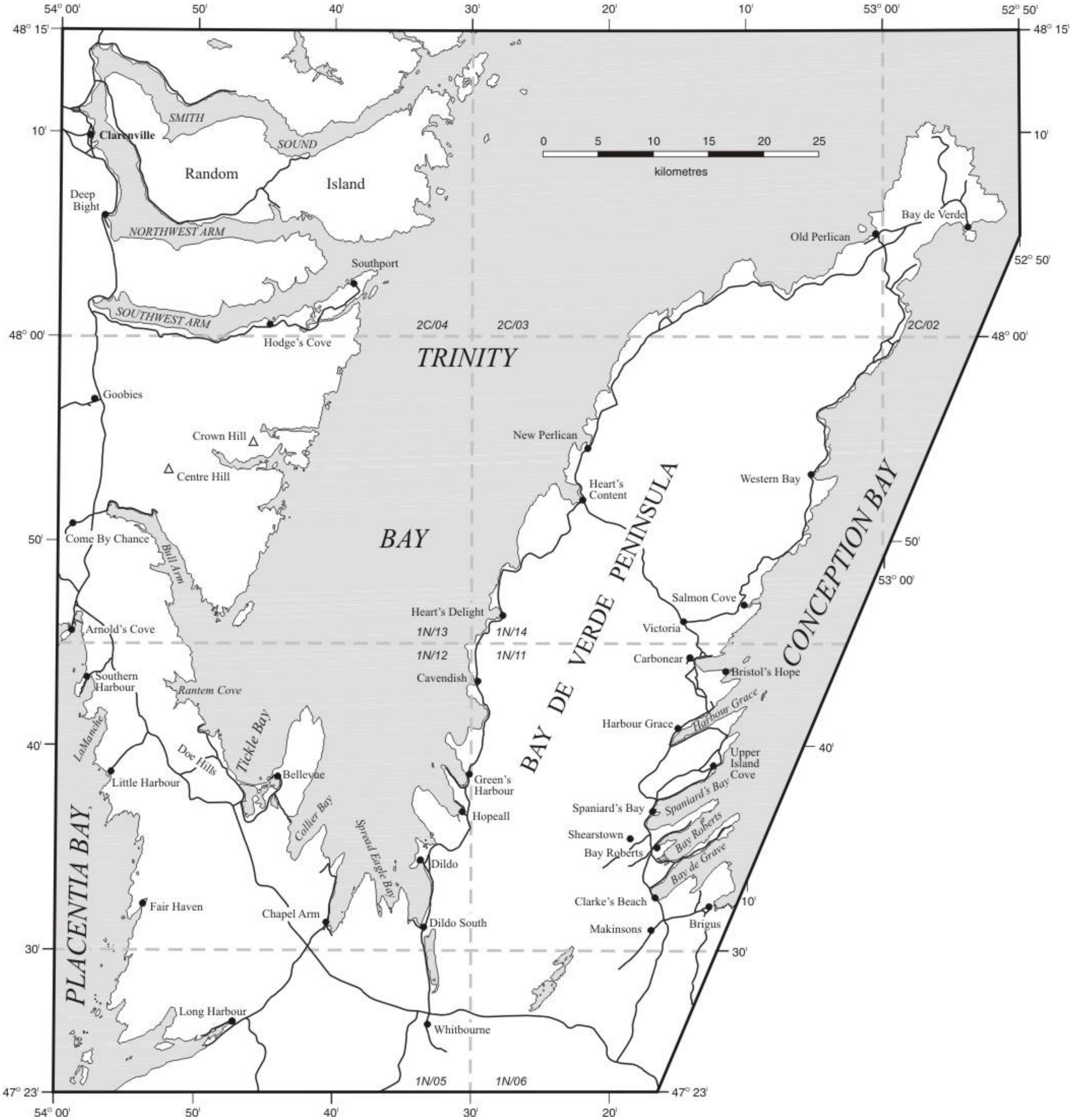

Figure 1. *Location of study area, and places mentioned in text.*

Access to the area was generally good, via a network of paved and gravel roads. The decommissioned Newfoundland railway track also provided access to areas on the Isthmus and the Bay de Verde Peninsula. Parts of the study area, however, were only accessible via helicopter. These included the area between Bull Arm and Southwest Arm, the eastern parts of the Isthmus, the Bellevue Peninsula and parts of the Bay de Verde Peninsula.

The study area is one of variable relief (Figure 2), ranging from the rugged coastal highlands north of Bull Arm to the gently rolling central Avalon lowlands characterized by a well-developed Rogen moraine field. The highest terrain is between Bull Arm and Southwest Arm, where Centre Hill extends to 515 m above sea level (m asl), and Crown Hill to over 365 m asl. Hills over 200 m asl are rare across the remainder of the field area, although the Doe Hills in the central Isthmus are over 350 m asl.

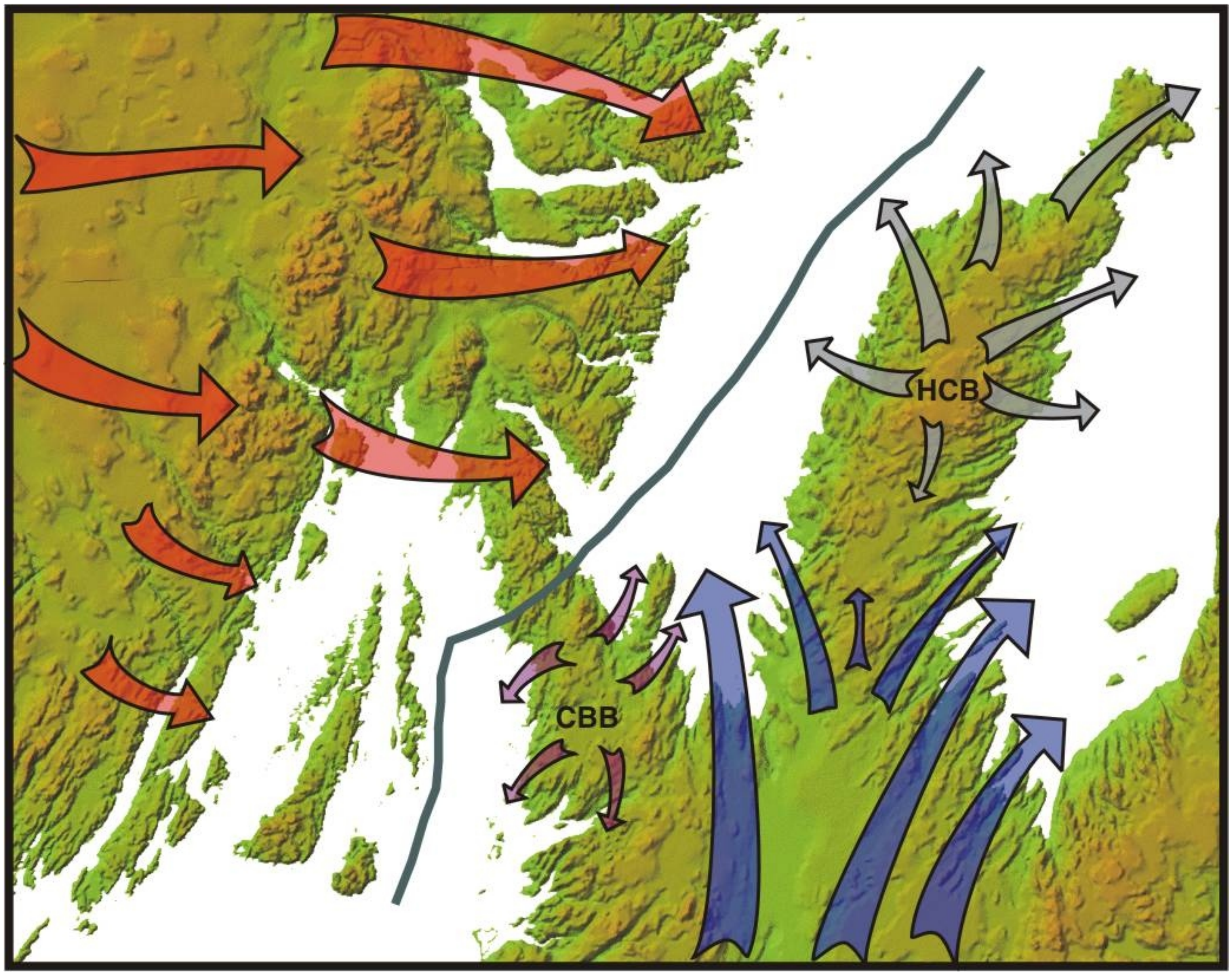

Figure 2. *Shaded-relief map and patterns of ice flow at the late Wisconsinan maximum (modified from Catto, 1998). Data shows that the western part of the study area was covered by ice from the main Newfoundland ice-dispersal centre (red arrows), likely on Middle Ridge. In contrast, the Avalon Peninsula was covered by radially flowing ice from a number of small dispersal centres located on the spine of the peninsulas. In the study area, ice flow was from dispersal centres at the head of St. Mary's Bay (blue arrows), Heart's Content barrens (HCB) and Collier Bay Brook (CBB).*

BEDROCK GEOLOGY AND MINERAL POTENTIAL

The study area lies entirely within the Avalon tectonostratigraphic zone. The bedrock consists of late Precambrian igneous and sedimentary rocks overlain by Palaeozoic shallow-marine and terrestrial sedimentary and minor volcanic rocks (O'Brien and King, 2002; O'Brien *et al.*, 1983; King, 1988; Figure 3).

Hadrynian sedimentary sequences of shallow-marine to fluvial rocks underlie most of the study area. The oldest are shallow-marine platformal rocks of the Conception Group, found on the western shore of Conception Bay, which are overlain by deltaic sedimentary rocks of the St. John's Group. The Connecting Point Group consists of early Hadrynian shallow marine sediments of similar age to the Signal Hill and Conception groups and is found in the west of the study area. These are overlain by fluvial sediments of the Signal Hill Group in the east, and the Musgravetown Group in the west. The Musgravetown Group contains felsic and mafic volcanic flows and tuffs found within the Bull Arm Formation. The Bull Arm Formation is intruded by the Hadrynian pink to grey, medium-grained Swift Current Granite.

Much of the remainder of the Avalon Peninsula and the Isthmus are underlain by small areas of younger rocks, the largest of which is shale and limestone of the Early Cambri-

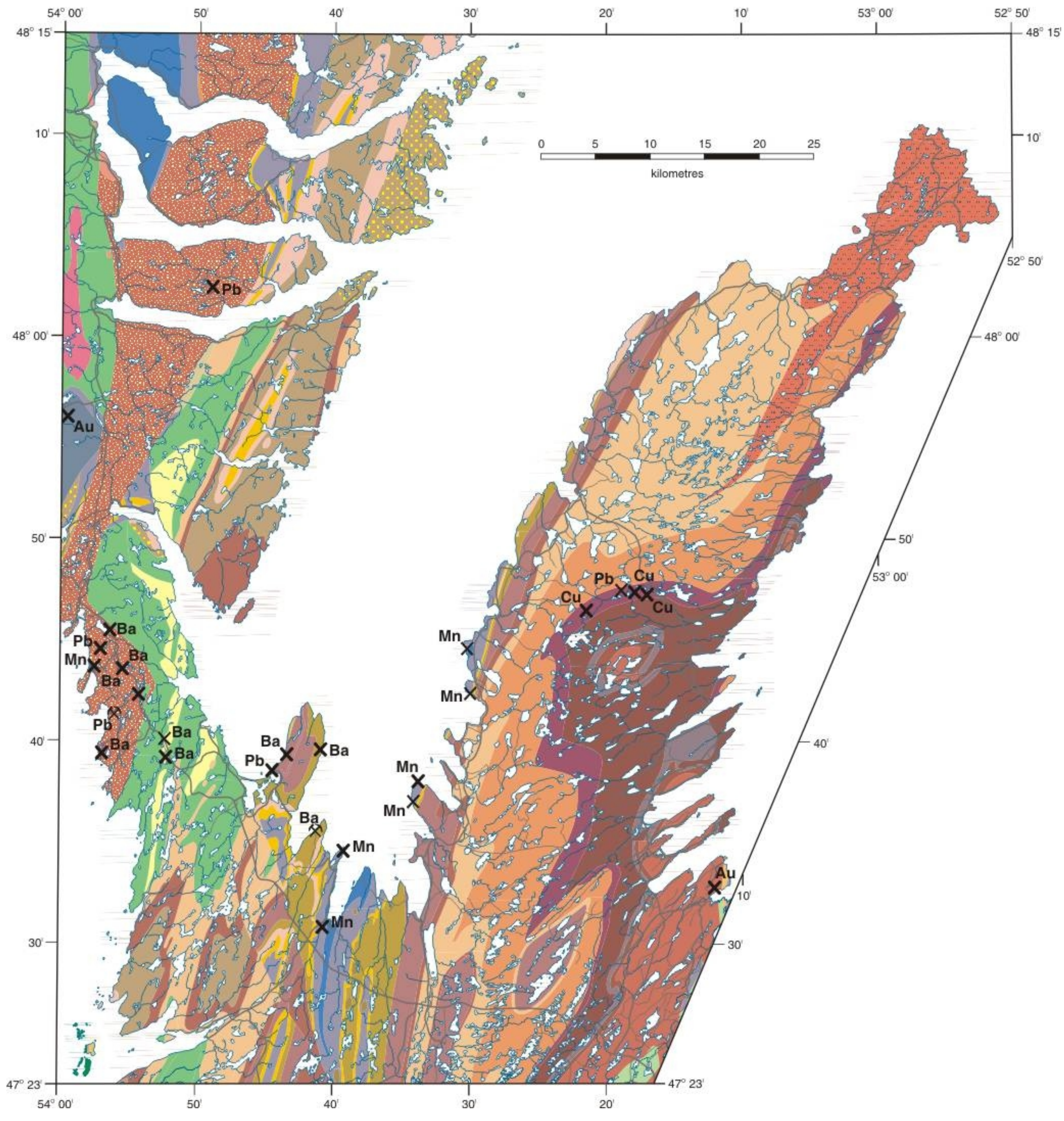

Figure 3. *Bedrock geology of the study area (after King, 1988).*

an to Middle Ordovician Adeytown Group. These rocks are found at the southeast end of Trinity Bay and along its eastern shore.

West of the Isthmus, the Hadrynian rocks are intruded by several granitic bodies, including the Devonian or earlier Clarenville Granite, a pink to red, medium-grained, biotite granite found along the western shore of Northwest Arm, and by the Powder Horn intrusive suite. The Powder Horn intrusive suite is composed mostly of fine- to medium-grained diorite, but also contains gabbro and minor granite (King, 1988).

The now-abandoned lead mine located within Conception Group strata at La Manche (Figure 2) on the north shore of Placentia Bay is one of the oldest mines in Newfound-

land, operating from the mid to late 1800s (Martin, 1983). More recently, the open-pit mine at Collier Point (Figure 2) extracted barite for the offshore oil industry. Several other barite showings are found across the Isthmus, mostly within the Connecting Point Group or Musgravetown Group. Other mineral occurrences include several manganese showings within the Adeytown Group, pyrrhotite found within St. John's Group rocks in the central Bay de Verde Peninsula, and copper exposed on the Heart's Content barrens within the St. John's Group. Recent exploration efforts have focussed on the potential for sediment-hosted or volcanic red-bed copper deposits within the Musgravetown Group (O'Brien and King, 2002). The discovery by Cornerstone Resources of copper mineralization within the Crown Hill Formation on the northern Bonavista Peninsula, and in volcanic rocks of the Bull Arm Formation has prompted exploration activity on the Isthmus and Avalon Peninsula, both of which are underlain by the Crown Hill and Bull Arm formations. Gold is found within the Powder Horn intrusive suite at the Lodestar gold showing, which is currently being prospected by Pathfinder Exploration.

ICE-FLOW HISTORY

PREVIOUS WORK

Much of the early work on the glaciation of the Avalon Peninsula suggested that the area was covered by eastward-flowing ice from central Newfoundland (Murray, 1883; Coleman, 1926; MacClintock and Twenhofel, 1940), although MacClintock and Twenhofel (*op. cit.*) argued that the Avalon Peninsula maintained an independent ice cap during deglaciation. Evidence of ice invading from the west is speculative and mostly based on clast provenance, e.g., Summers (1949) notes the presence of serpentinite clasts near St. John's. This may be sourced off the Avalon Peninsula, although D. Bragg (personal communication, 2001) reports serpentinite-rich veins in the Cochrane Pond area. There is no erosional evidence (e.g., striations) for invasion from the west.

The erosional data suggest that the Avalon Peninsula maintained an independent ice cap during the late Wisconsinan. Chamberlin (1895) was the first to suggest this, but subsequently the idea has been well acknowledged (e.g., Vhay, 1937; Summers, 1949; Jenness, 1963; Henderson, 1972; Catto, 1998). The main ice dome was likely at the head of St. Mary's Bay (Henderson, 1972; Catto, 1998), with ice flowing radially, but particularly over the low cols to the north and northwest into the Trinity and Conception bay watersheds; the Rogen moraines found south of Whitbourne formed during this northward flow. The radial flow from St. Mary's Bay had little effect on intervening peninsulas, which likely maintained their own ice caps (Summers, 1949; Catto, 1998). Similarly, the Isthmus area east of the Doe Hills was covered by ice from a local source. West of the Doe Hills, the area was covered by ice from the main part of the Island (Catto, 1998). This is supported by striations and the provenance of clasts in till.

ICE-FLOW MAPPING

The favoured method of delineating ice flow is by mapping striations on bedrock (Batterson and Liverman, 2001). Striations are excellent indicators of ice flow as they are formed by the direct action of moving ice. Data from individual striations should be treated with caution, as ice-flow patterns can show considerable local variation where ice flow was deflected by local topography. Regional flow patterns can only be deduced after examining numerous striated sites. The orientation of ice flow can easily be discerned from a striation by measuring its azimuth. Determination of the direction of flow can be made by observing the striation pattern over the outcrop. For example, areas in the lee of ice flow may not be striated. The presence of such features as ‘nail-head’ striations (Plate 1), miniature crag-and-tails (rat-tails), and the morphology of the bedrock surface may all show the effects of sculpturing by ice (Iverson, 1991). At many sites, the direction of ice flow is unclear and only the overall orientation of ice flow (e.g., north or south) can be deduced. Where striations representing separate flow events are found, the age relationships are based on crosscutting striation sets, and preservation of older striations in the lee of younger striations.

Striation data for Newfoundland and Labrador are compiled in a web-accessible database (Taylor, 2001), which currently contains over 10 700 observations. Ice flow is interpreted from striations and additional data from large-scale landforms such as erosional rôche moutonée features or depositional features such as Rogen moraines. Clast provenance also helped confirm glacial source areas.

RESULTS

Paleo ice-flow history was determined from over 1300 striation observations from across the study area, of which 86 were collected during this project. Striations were fresh, and unweathered. Where two or more sets of striations were found at a site, the older striations showed no evidence (e.g., iron staining) of survival through a non-glacial period. Therefore, all striations were considered to have been produced during the late Wisconsinan. Data are summarized on Figure 2 and generally conform with the detailed ice reconstruction of Catto (1998). Within the study area, Avalon-centred ice extended northwest across the Isthmus to the Doe Hills, north of which, eastward-flowing ice dominates. This is consistent with the reconstruction of Batterson and Taylor (2001) that showed much of the area south and west of

Plate 1. *Well-developed nailhead striations on the Avalon Peninsula. These features may be interpreted to show paleo ice-flow directions. Data is compiled in the Newfoundland and Labrador striation database (Taylor, 2001).*

Clarenville was covered by eastward-flowing ice from the Middle Ridge area of central Newfoundland. This flow crossed the northern part of Placentia Bay from the Burin Peninsula, as indicated by the presence of eastward-oriented crag-and-tail hills on the west side of the Isthmus (Catto and Taylor, 1998a). Preliminary work shows the presence of granite, mafic volcanic and quartzite clasts in tills, likely derived from the Burin Peninsula.

South of the Doe Hills there is no evidence of ice flow from the area to the west. The striation patterns and the presence of clasts derived from local bedrock suggest that ice flow from 3 separate local sources covered the study area during the late Wisconsinan. The southern parts of the Bay de Verde Peninsula, Trinity Bay and Conception Bay were covered by northward-flowing ice from the main Avalon ice centre at the head of St. Mary’s Bay. On the Bay de Verde Peninsula, topography had a profound influence on ice-flow patterns, and in particular by the configuration of bays and inlets. Ice-flow indicators are consistently oriented parallel to major, bedrock-controlled embayments, e.g., Harbour Grace, Bay Roberts, Bay de Grave.

The Isthmus and the Bay de Verde Peninsula both maintained their own ice caps, from which ice flow was radial. The Isthmus ice cap was centred on the Collier Bay Brook area, and the Bay de Verde ice cap was located on the barrens to the east of Heart’s Content (Catto, 1998). Within these areas, clasts found in till are consistently locally derived.

SURFICIAL GEOLOGY

The surficial geology of much of the study area was mapped by Catto and Taylor (1998a to f). These maps will be revised, if necessary, based on field work from this study.

Section descriptions of Quaternary exposures will be completed in subsequent years. The following discussion is based on the work of Catto and Taylor (*op. cit.*) and supplemented by recent observations.

The surficial geology within the study area is summarized in Figure 4. It is subdivided into 5 main categories, viz., bedrock, till, glaciofluvial, raised marine and modern sediments.

BEDROCK

Outcrops of bedrock are found over much of the study area, although large expanses of bedrock-dominated terrain are restricted to the higher parts of the Isthmus and the highlands between Bull Arm and Northwest Arm, most of the Bellevue Peninsula, and the west side of Conception Bay. Bedrock exposed at the surface is commonly streamlined (Plate 2). Bedrock outcrop is rare within the Rogen moraine field (*see below*) that extends southward across the central Avalon lowland.

TILL

Till, of varying thickness and composition, is by far the most aerially extensive unit on the Avalon Peninsula. It commonly occurs as a veneer over bedrock, particularly over the Bay de Verde Peninsula and the central Isthmus and has numerous bedrock outcrops exposed within it. An examination of tills indicates that they have consistent characteristics over a wide area. On the Bay de Verde Peninsula, for instance, tills are commonly poorly consolidated, very poorly sorted to unsorted, with a silty sand matrix. Clast content varies from 30 to 60 percent by volume, and clast rock types are derived mainly from the underlying bedrock. Fine-grained rocks are commonly striated. Exotic clasts were rare to absent. In contrast, tills to the west of the Doe Hills are commonly finer grained, and contain numerous exotic clasts reflective of dispersal from the west. These observations agree with those of Catto (1998).

Till mostly forms either a veneer or blanket over bedrock and few areas of constructional landforms were found. The west side of the Isthmus contains crag-and-tail hills, up to 800 m long, 300 m wide and 30 m high. These are oriented northeastward, in agreement with the local striation record, but in contrast to the reconstruction of Catto (1998). The southern part of the Bay de Verde Peninsula contains part of the central Avalon Rogen moraine field (Plate 3). The moraines are commonly crescent-shaped, and curved in the direction of glacial movement, which was northward from the St. Mary's Bay ice-dispersal centre. The Rogen moraines are up to 30 m high, and are spaced 200 to 400 m apart. They are composed mostly of till, although some sorted sand and gravel is present. They are commonly found adjacent to small ponds. These features are formed beneath actively flowing ice, although the actual method of formation has been the subject of considerable debate. Lundqvist (1969) argues for squeezing of sediment into subglacial cavities; Boulton (1987) suggests wholesale deformation of subglacial sediment; a melt-out hypothesis is favoured by Bouchard (1989) and Aylsworth and Shilts (1989); and formation by subglacial meltwater is proposed by Fisher and Shaw (1992), based on work on the Avalon moraines.

GLACIOFLUVIAL SEDIMENT

Small areas of glaciofluvial sand and gravel are exposed on the Bay de Verde Peninsula, all of which are currently being exploited for granular aggregate production. Both ice-contact and ice-distal glaciofluvial deposits were identified. At Makinsons, extensive pits within the broad South Brook valley expose ice-contact sediments (Plates 4 and 5). The sediments display considerable vertical and lateral variation in both texture and sedimentary structures. These include high-angle, poorly sorted, coarse gravelly sand beds and horizontal rhythmically bedded silt and fine sand. Faulted beds and slump features were noted on pit walls. The faults, slumps and high-angle beds are consistent with collapse from melting of ice blocks, and the fine-grained beds were likely deposited within small ponds on the disintegrating glacier surface.

In the Shearstown Brook valley, which opens into Spaniard's Bay, aggregate operations reveal flat-lying terraced sand and gravel deposits (Plate 6). The sediment is a moderately sorted, roughly horizontally bedded to crossbedded, coarse sandy gravel. Crossbeds indicate paleo flow to the northeast (down-valley). Clasts range up to about 15 cm diameter and the sediment lacks the large boulders characteristic of the Makinsons exposures. These sediments were likely deposited in an ice-distal glaciofluvial environment.

RAISED MARINE SEDIMENT

The paleo sea-level history of the Avalon Peninsula is poorly understood. Grant (1987) suggested that the 0 m isopleth crosses the Avalon Peninsula and lies roughly between Long Harbour and Chapel Arm, extending northward along the western shore of the Bay de Verde Peninsula. The area to the west of this line, therefore, has a Type B paleo sea-level history (Quinlan and Beaumont, 1981), with a period of raised sea levels following deglaciation and a subsequent fall to a lowstand position from which sea level has gradually recovered to the present. To the east, the paleo sea-level history is characterized as being always below modern levels, with no raised marine features occurring. However, this

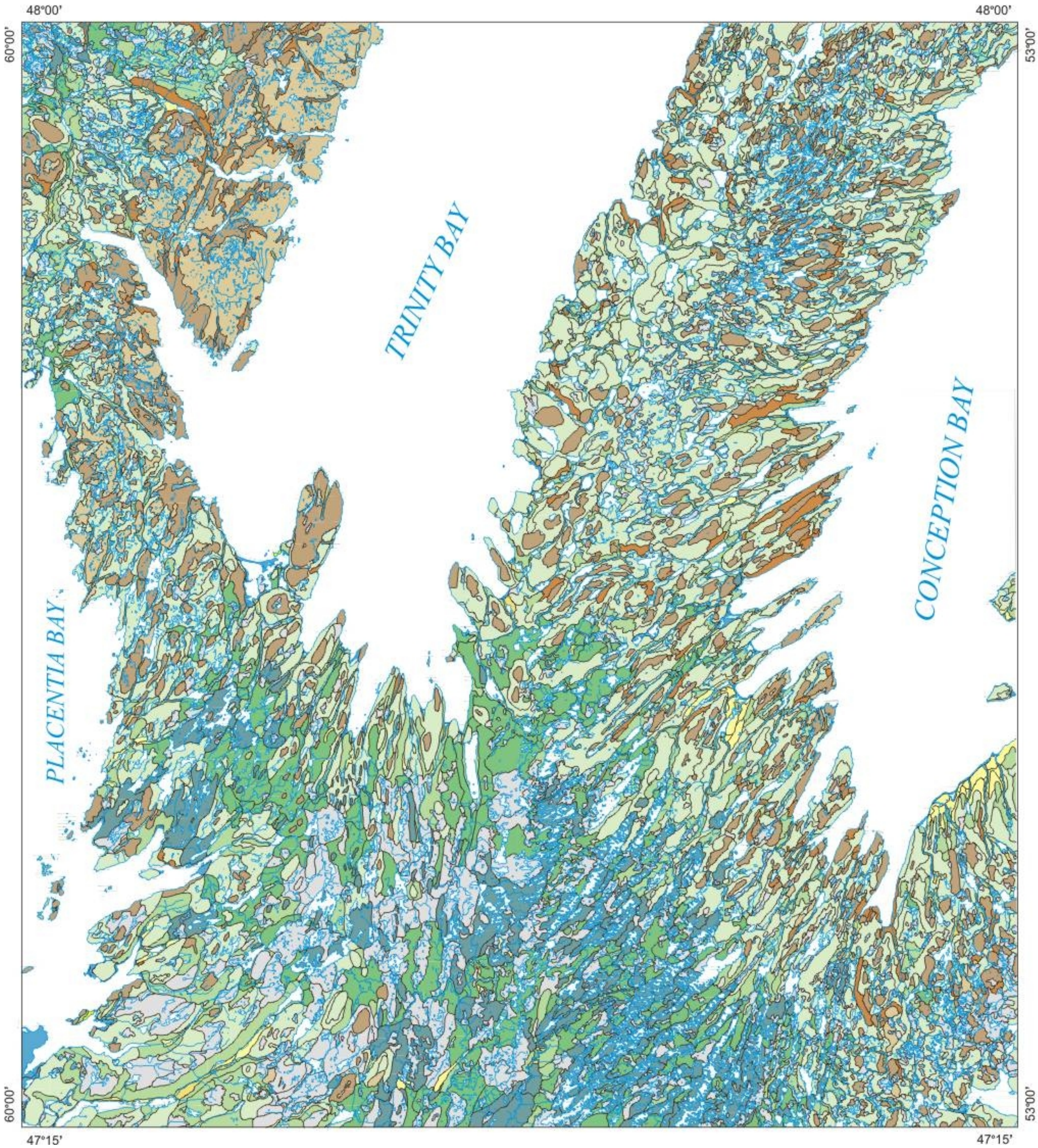

Figure 4. *Surficial geology of the study area (after Catto and Taylor, 1998a to f), mostly based on aerial photographic interpretation with some ground verification of surficial units.*

hypothesis has been challenged by Catto and Taylor (1998a) who mapped raised marine sediments in the Argentia area and at the head of St. Mary's Bay.

Within the study area, raised marine deposits were found at several localities on the Isthmus and Bay de Verde Peninsula. At Southern Harbour, a raised beach having a surface elevation of 13 m asl was noted (Plate 7). The beach consists of open work gravels containing angular to subangular clasts up to 10 cm diameter, and a mean of 3 cm diameter. At Dildo South, raised beach sediments were found with a surface elevation of 14.5 m asl, and raised marine ter-

LEGEND (Figure 4)

- ***Bog:*** Accumulations of degraded organic matter deposited in poorly drained low lying areas
- ***Colluvium:*** Accumulations of poorly sorted detritus around the base of steep hills derived from the slopes above
- ***Fluvial:*** Moderate to well sorted gravel, sand, silt and clay deposited in modern river systems
- ***Marine:*** Moderately to well sorted gravel, sand and mud. Mostly exposed in marine terraces
- ***Glaciofluvial:*** Poorly to well sorted sand and gravel, 1.5 to 50 m thick
- ***Till veneer:*** Thin (less than 1.5 m) discontinuous sheet of till overlying bedrock. Patches of exposed bedrock and thicker sediment common. Relief and topography variable
- ***Till blanket:*** Continuous till cover thicker than 1.5 m. Includes areas of eroded till
- ***Hummocky till:*** A blanket of till having an irregular hummocky topography and relief of 2 to 10 m. Hummocks mostly till, but may contain sand and gravel
- ***Ridged till:*** Blanket of till having topography consisting of ridges oriented parallel or perpendicular to ice flow
- ***Concealed bedrock:*** Mainly bedrock concealed by vegetation with patches of till, sand and gravel, and bog, and exposed bedrock
- ***Exposed bedrock:*** Areas of bedrock with little or no surface sediment

Plate 2. *Streamlined bedrock landform on the Bay de Verde Peninsula. These features are particularly well developed close to the coast where they commonly parallel the bedrock-controlled bays.*

races were noted at Heart's Delight (11 to 12 m asl) and Heart's Content (9 m asl). The age of these surfaces remains speculative as no marine shells were found within the Quaternary deposits.

Plate 3. *Rogen moraine south of Whitbourne. These features are oriented perpendicular to ice flow and are formed in a subglacial environment. The Rogen moraines on the Avalon Peninsula were formed by northward-flowing ice, or subglacial water, from a dispersal centre at the head of St. Mary's Bay.*

Plate 4. *Steeply dipping and contorted sand and gravel beds in a pit at Makinsons. These sediments were deposited in an ice-contact glaciofluvial environment.*

MODERN SEDIMENT

Modern sediments include fluvial sand, gravel and silt (alluvium) found adjacent to modern streams, colluvium at the base of steep hills, modern marine deposits such as beaches and tidal flats, and aeolian deposits. Each of these sediment classes is found in small areas across the study area. The most aerially extensive modern fluvial deposits are found in the Shearstown Brook valley and the South Brook valley, which opens into Bay de Verde. Rivers in these valleys have partially reworked their thick glaciofluvial sediments. Other thin veneers of alluvium were identi-

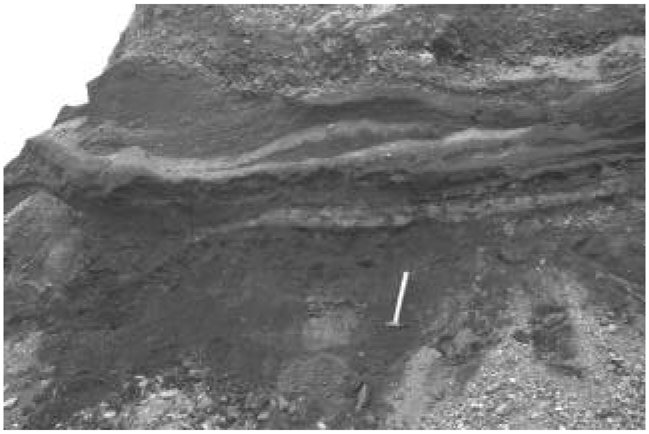

Plate 5. *Flat-lying sandy silt and sand beds truncated by sand and gravel beds found in a pit at Makinsons. These sediments are adjacent to those shown in Plate 4. Sediments exposed at Makinsons were likely deposited in an ice-contact glaciofluvial environment. The fine-grained sediment shown was likely deposited in a supraglacial pond.*

Plate 6. *Planar horizontally bedded sand and gravel exposed at a pit near Shearstown. They are found within a terrace above the modern river. These sediments show no evidence of ice-contact sedimentation, and in contrast to sediments found in the pits at Makinsons, were deposited in an ice-distal glaciofluvial environment.*

fied by Catto and Taylor (1998c, d), including those along the South River, Island Pond Brook and Mosquito Brook valleys draining into Conception Bay, and Murphy's Cove Brook and Collier Bay Brook draining into Trinity Bay. Many other small, unnamed stream valleys also contain thin fluvial deposits over bedrock.

The largest areas of colluvium were identified on the highlands between Bull Arm and Northwest Arm, and on the eastern side of the Bay de Verde Peninsula between Spaniard’s Bay and Carbonear. Several of these areas contain active slopes, including that at Upper Island Cove, where a rockfall in 1999 damaged a house and car.

Plate 7. *Raised beach found at Southern Harbour having a surface elevation of 13 m asl. The beach consists of openwork gravel. Raised marine features were found at several locations on the Trinity Bay and Placentia Bay coasts, all at modern elevations of below 15 m.*

Much of the coastline in the study area is steep and bedrock-dominated. Beaches are commonly restricted to small, gravel-dominated, high-energy, pocket beaches. Barachois beaches were identified at several localities, including Southern Harbour, Rantem Cove, Spread Eagle Bay, Chapel Arm, Cavendish Bay, Clarke’s Beach, Bay Roberts and Bristol’s Hope (Figure 1). All are gravel-dominated, commonly less than 500 m long, and exhibit a variety of structures, including small- and large-scale cuspate features, and beach berms where the backbeach areas commonly exhibit overwash fans. Sand components commonly exhibit wave ripples. The largest barachois beach and spit complex is Bellevue Beach (Plate 8), which is over 1 km long. This area has an extensive backbeach system, with well-developed overwash fans and active sand dunes. An unusual tidal flat complex is found at the head of Come-by-Chance, where large boulders are littered over a sand-dominated flat. Catto and Thistle (1993) suggest that this is an eroded glaciofluvial fan from which all but the boulders have been re-worked by the tide.

Several small areas of aeolian sediment were located at Bellevue and Hodge’s Cove, mostly as a veneer over till. Active sand dunes are present in the backbeach area of Salmon Cove (Figure 1).

Areas of organic accumulation are common across the entire area, mostly less than 50 cm thick, although pockets of bog likely extend beyond 3 m in depth.

REGIONAL TILL SAMPLING

A regional till-sampling program was conducted using the surficial geology as a guide. Glaciofluvial, fluvial, marine, and aeolian sediments were excluded. Most samples were from the C- or BC-soil horizon, taken at about 0.5 m

Plate 8. *Modern barachois beach at Bellevue. Much of the beach system is within Bellevue Beach park. Barachois beaches are common around the modern coast.*

depth in test pits, or 0.5 to 1.0 m depth in quarries or road cuts. In rare instances, the lack of surface sediment necessitated the sampling of bedrock detritus. Sample spacing was controlled by access as well as surficial geology. In areas with good access, the sample density was about 1 sample per 1 km^2, increasing to about 1 sample per 4 km^2 in areas where helicopter support was required. Samples were passed through a 5 mm-mesh sieve and approximately 1 kg of the sample was retained for analysis.

A total of 1042 samples were collected (Figure 5) and submitted to the Geological Survey's geochemical laboratory in St. John's for major- and trace-element analysis. The methods and the elements analysed are summarized in Table 1. Data quality is monitored using field and laboratory duplicates (analytical precision only) and standard reference materials. In all cases, the silt–clay fraction (less than 0.063 mm) is analyzed. Data release is anticipated by the summer of 2003.

IMPLICATIONS FOR MINERAL EXPLORATION

For the purposes of discussion, the study area is divided into 4 discrete subareas: north of the Doe Hills; southern Isthmus; southern Bay de Verde Peninsula; and central Bay de Verde Peninsula.

NORTH OF THE DOE HILLS

Paleo ice-flow indicates that during the late Wisconsinan the area north of the Doe Hills was covered by eastward-flowing ice, likely from the main Newfoundland dispersal centre on Middle Ridge. Till contains clasts derived from the west. Transportation distances are commonly greater than 5 km. Batterson and Taylor (2001a) documented dispersal of granite clasts on the Bonavista Peninsula by eastward-flowing ice at least 50 km from their source in the Clarenville area.

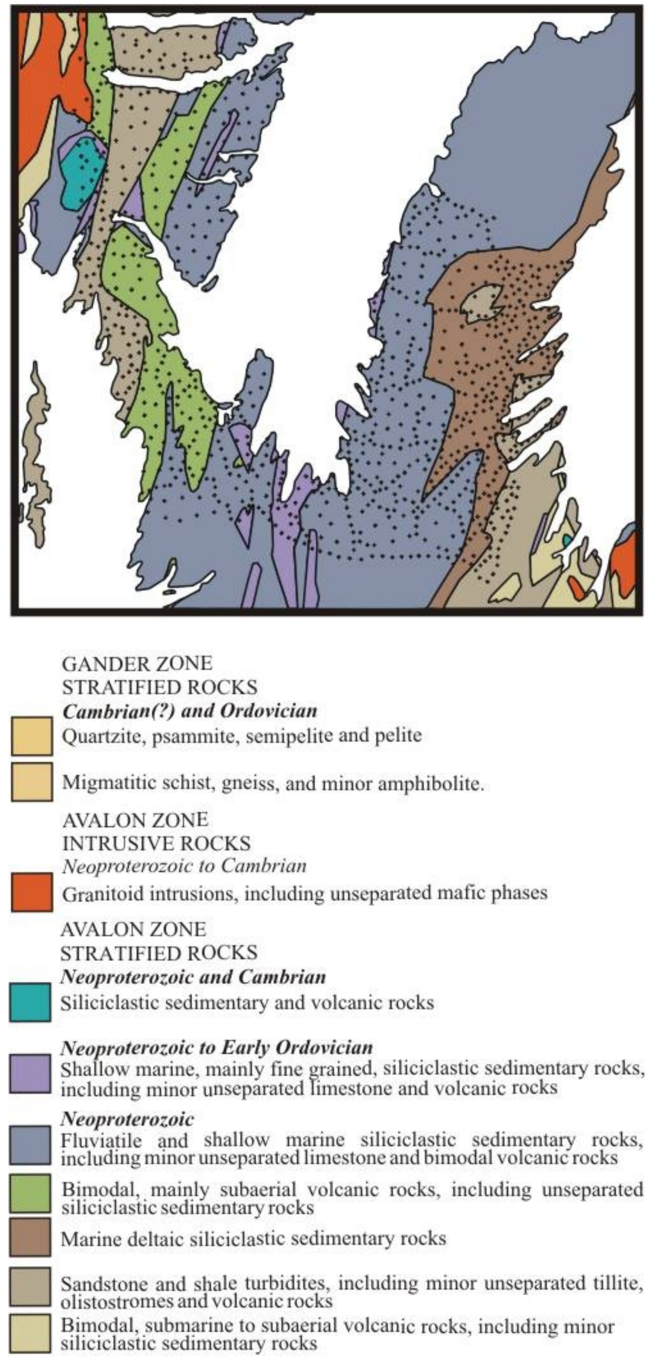

Figure 5. *Location of till samples for which geochemistry will be completed. Sites are overlain on a simplified bedrock geology base taken from Colman-Sadd* et al. *(1990).*

SOUTHERN ISTHMUS

The southern part of the Isthmus was covered by a small ice cap during the late Wisconsinan centred on the Tickle Harbour Station–Collier Bay Brook area (Figure 2). Paleo ice-flow radiated from this centre into Placentia Bay and Trinity Bay. Diamictons are characteristically dominat-

Table 1. Elements analysed by GSNL and commercial laboratories

Method	**Elements analysed**
Atomic absorption spectrophotometry (AAS)	Ag
Gravimetric analysis	LOI (Loss-on-ignition)
Inductively coupled plasma emission spectrometry (ICP)	Al, Ba, Be, Ca, Ce, Co, Cr, Cu, Dy, Fe, Ga, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Sc, Sr, Ti, V, Y, Zn, Zr
Instrumental neutron activation analysis (INAA)	As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Na, Nd, Rb, Sb, Sc, Sm, Tb, Th, U and Yb,

ed by locally derived clasts, and distances of transport are considered to be less then 5 km.

SOUTHERN BAY DE VERDE PENINSULA

Ice from the St. Mary's Bay dispersal centre covered much of the southern part of the Bay de Verde Peninsula. The influence of topography is noted by the movement of ice into Trinity Bay on the west and Conception Bay on the east side of the peninsula. Ice flow commonly was parallel to the orientation of the major bays on both coasts. Northward-flowing St. Mary's Bay ice produced the Rogen moraines that characterize the central Avalon Peninsula. The mode of formation of these moraines may be unimportant to prospecting in the area. If formed of diamicton during active subglacial ice flow by a compressive flow regime, these features may reflect local derivation. If, however, they were formed by erosion during a subglacial flood event they are likely also composed of locally derived material, although partially transported in a glaciofluvial system. Further work on these features is required to determine their mode of formation.

CENTRAL BAY DE VERDE PENINSULA

The central part of the Bay de Verde Peninsula maintained its own ice cap during the late Wisconsinan. Paleo ice-flow from this centre was radial. Diamictons characteristically contain clasts from the underlying bedrock and erratics are absent from this area. Dispersal distances are therefore considered to be less than 5 km.

Areas of glaciofluvial sedimentation are well defined on published surficial maps and should be treated separately from diamictons in a regional till-geochemistry program. Much of the coastline shows evidence of having been raised up to about 15 m above modern sea level following deglaciation. Marine sediments, due to the uncertainty in source directions and distances of transport (e.g., possibly iceberg derived), should be avoided in exploration programs. Colluvium is derived from the overlying slopes and therefore provides point source geochemical data.

PROJECT DEVELOPMENT

This is the second year of a multi-year Quaternary mapping and till-geochemistry project in eastern Newfoundland, following on from the work of Batterson and Taylor (2001b). Revised surficial geology maps of the study area and open file reports of the till geochemistry will be released by summer 2003. Subsequent work will focus on completing mapping and sampling of the remainder of the Avalon Peninsula, including the northern Burin Peninsula.

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